ALS-U Project

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BNL Beamline Engineering Meeting
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BERKELEY LAB

U.S. DEPARTMENT OF ENERGY | Office of Science

ALS-U
ADVANCED LIGHT SOURCE

Outline

- An introduction to ALS-U
- Bending magnet beamline moves
- New and Upgraded ID beamlines
- Technical challenges
- Engineering needs
- Conclusions

An introduction to ALS-U

- Goals
- Accelerator Scope
- Beamline scope

ALS-U high-level performance goals

- Achieve an increase in brightness and soft x-ray coherent flux (@1 keV) of at least two orders of magnitude beyond today's ALS capabilities
- Develop a set of experimental capabilities that will enable leadership in soft x-ray science
- Provide infrared capability that extends across the wavelength range provided at the present-day ALS
- Provide hard x-ray capability comparable to the present-day ALS

ALS-U CD-1 project scope

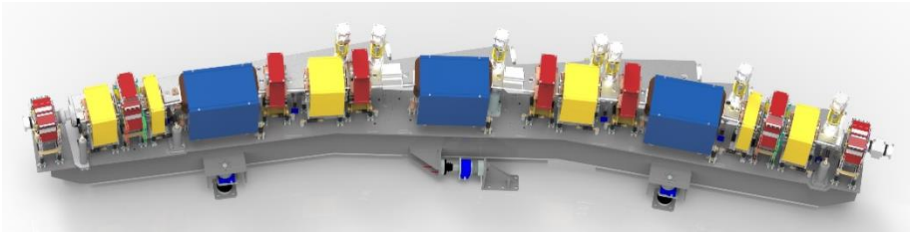
Accelerator

- New 2 GeV MBA high-brightness storage-ring lattice in existing storage-ring tunnel
- New full-energy accumulator ring and transfer lines in existing ring tunnel
- 3 new insertion devices
- 6 high-field replacement of superbends

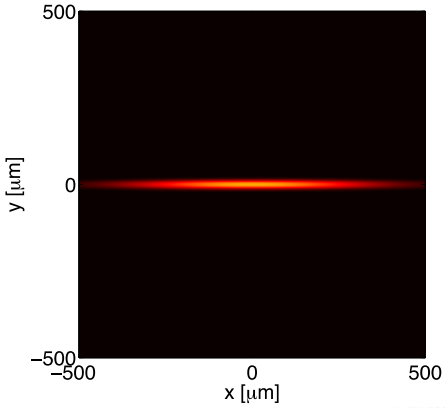
Beamlines

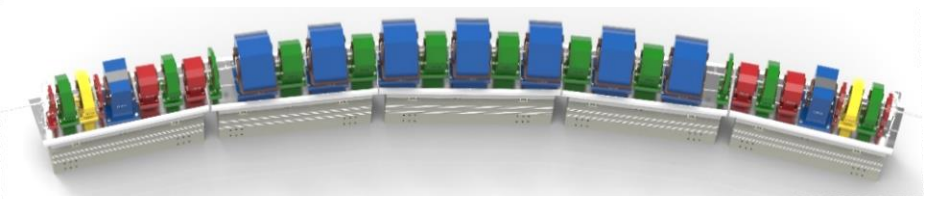
- A suite of 2 new and 2 upgraded world-leading ID beamlines
- Retention of existing ID beamline capability
- Retention and realignment of bend-magnet beamlines

Nine bend MBA lattice and fundamental parameters

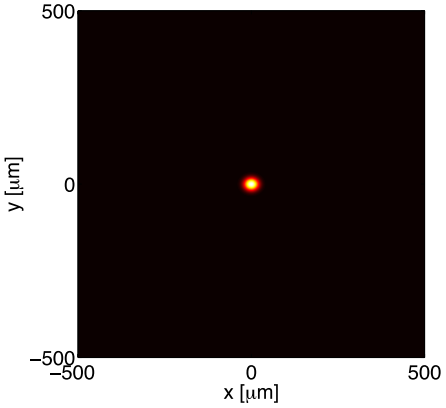


ALS





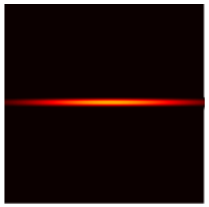
ALS-U

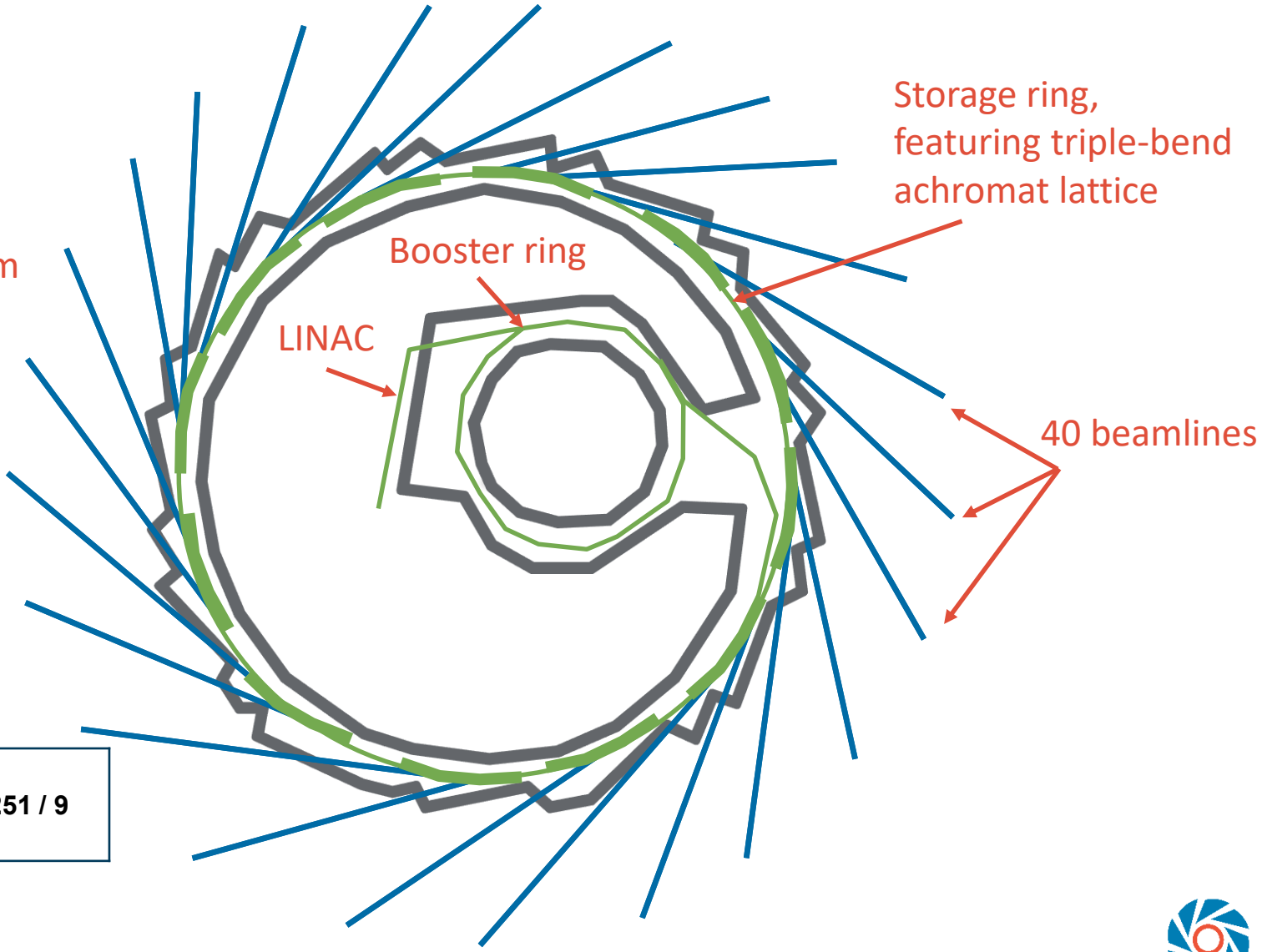


parameter	ALS	ALS-U	units
electron energy	1.9	2.0	GeV
beam current	500	500	mA
Horizontal emittance	2000	≤ 75	pm rad
Vertical emittance	30	≤ 75	pm rad
beamsize (σ_x/σ_y) @ ID center	251 / 9	≤ 14 / ≤ 14	μm
beamsize (σ_x/σ_y) @ x.3 bend	40 / 7	≤ 7 / ≤ 10	μm
bunch len. (FWHM) harmonic cavity	60–70	100–200	ps
No. of bunches	296+1 (hybrid)	284 (11 trains)	
energy spread	9.7e-4	1.1e-3	ΔE / E
RF frequency	500	500	MHz
circumference	196.8	~196.5	m

The ALS today has…

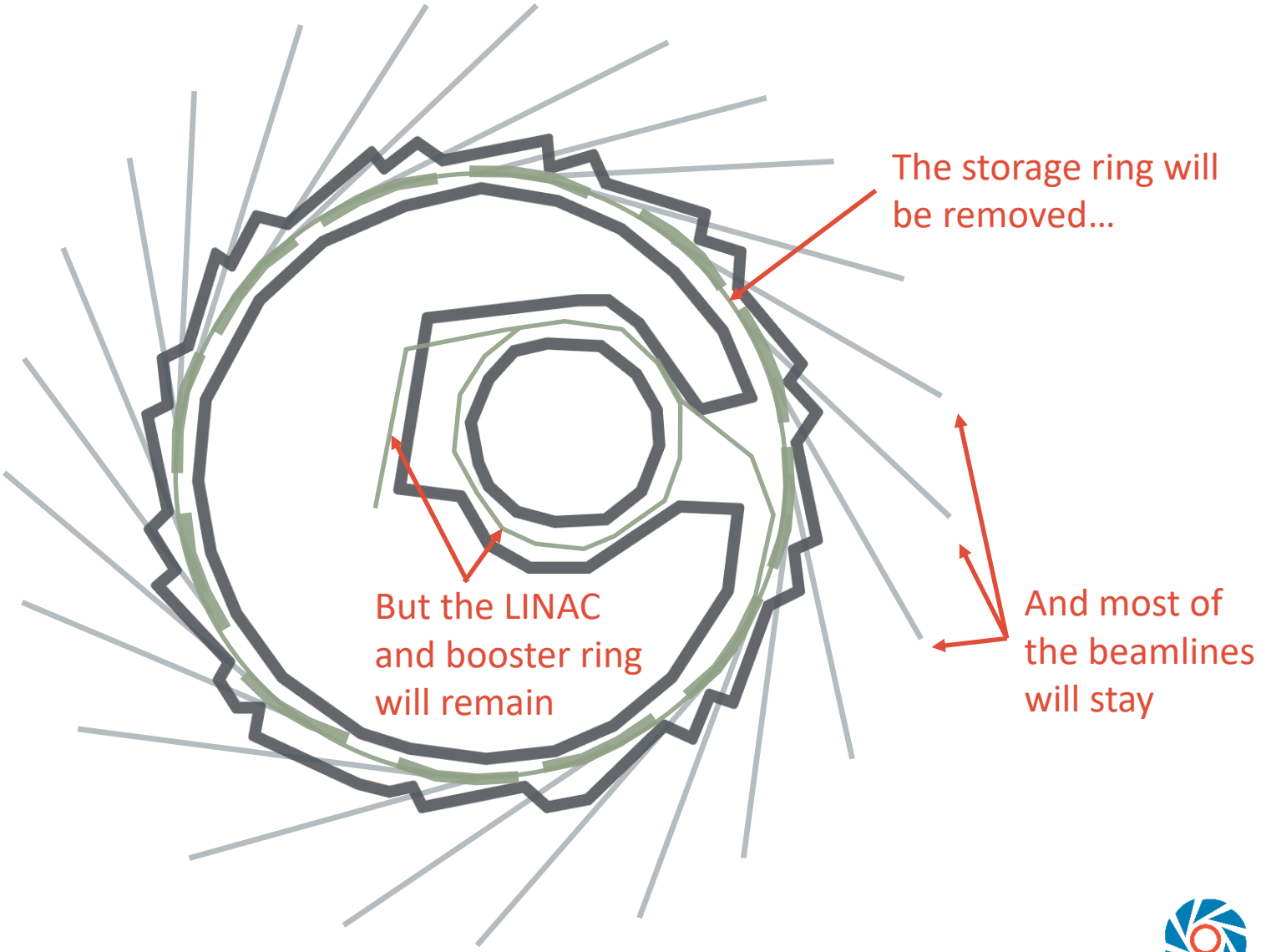
Thin, wide electron beam profile



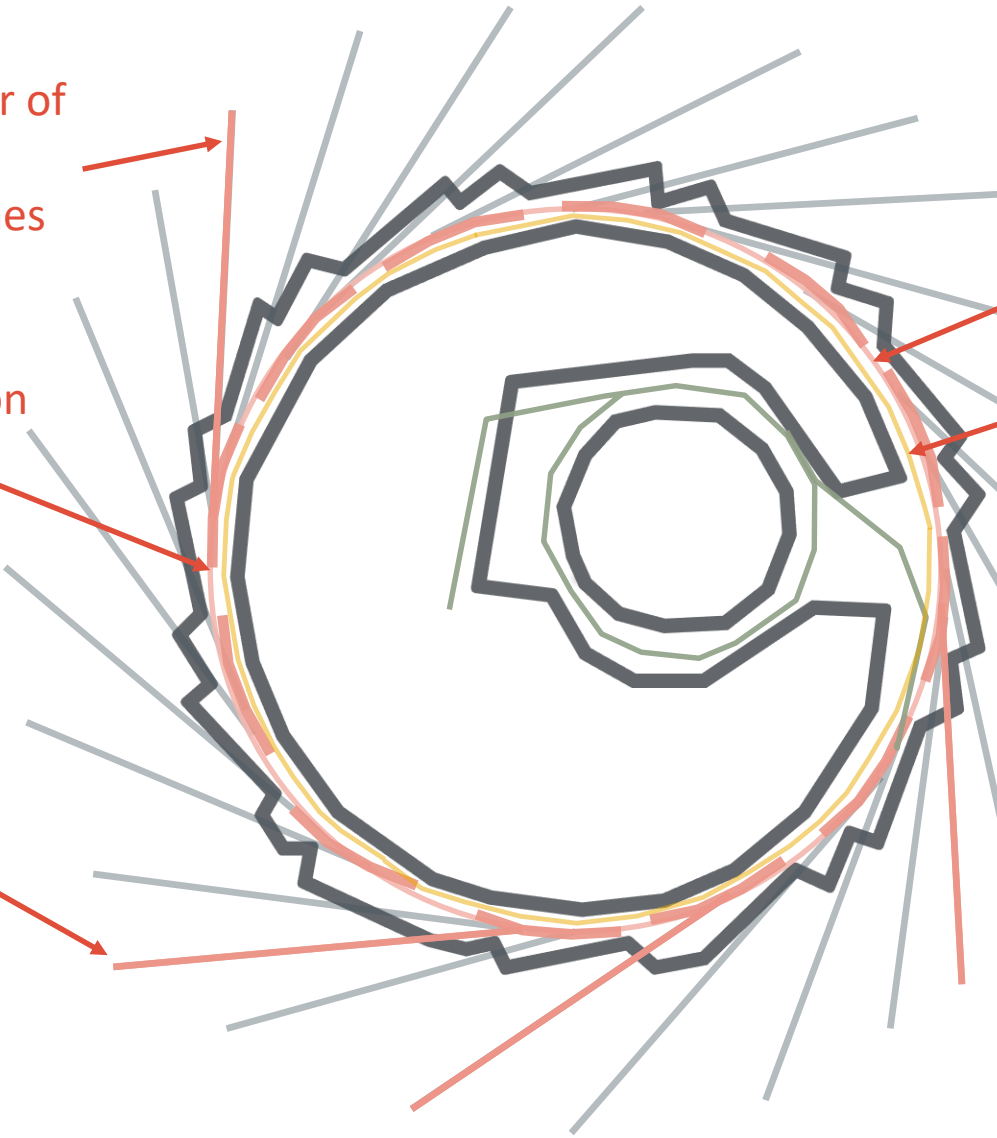


beamsize (σ_x/σ_y) @ ID center	**251 / 9**

During the ALS-U project…



During the ALS-U project…



A small number of new insertion-device beamlines will be added

Some new insertion devices will be added to the ring

And a small number of insertion-device beamlines will be upgraded

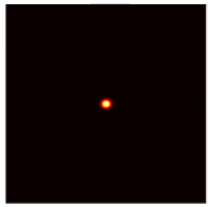
A new storage ring will be built, based on a 9-bend achromat

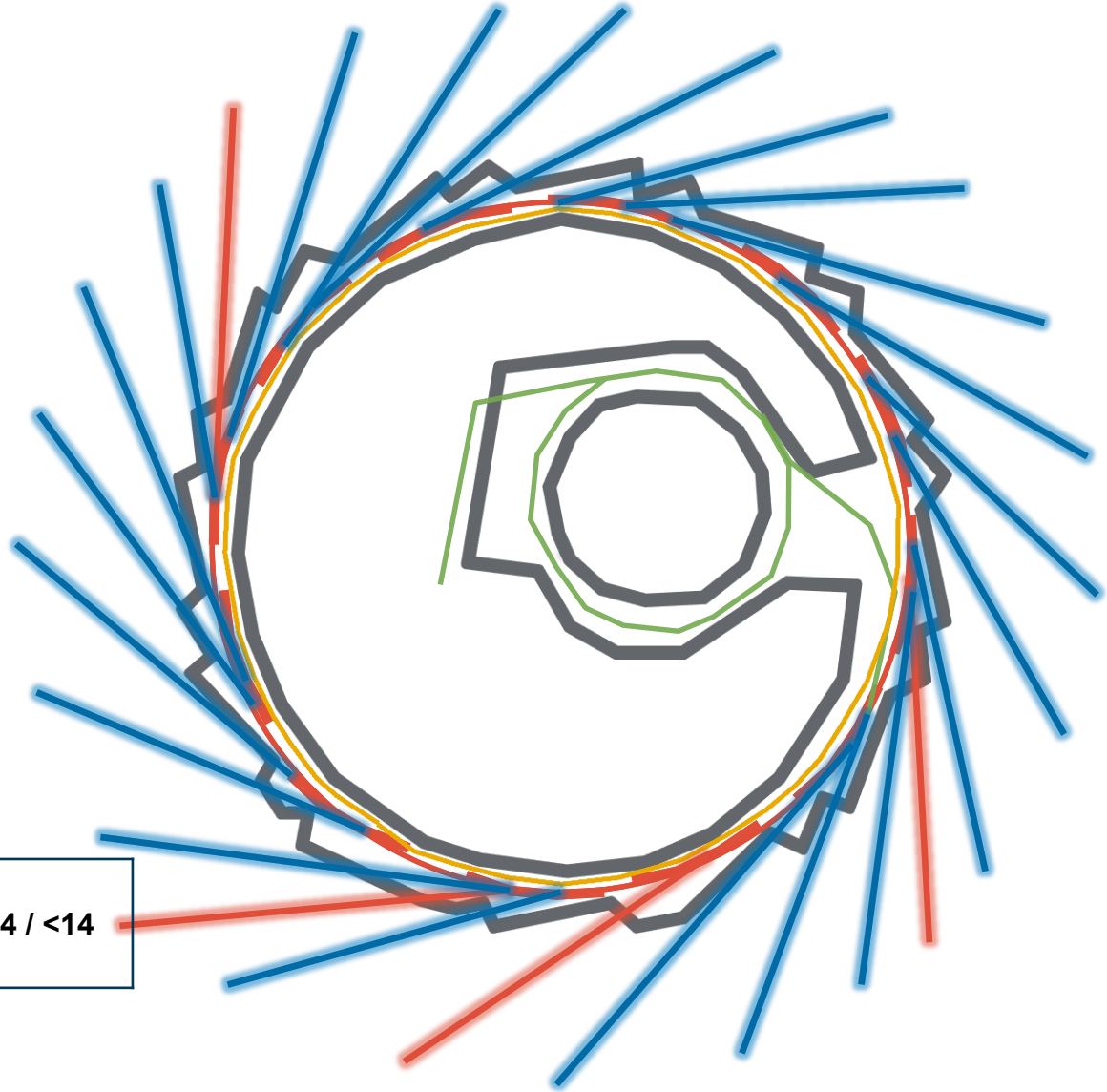
And a second concentric "accumulator" ring will be added

Bend and superbend beamlines will be realigned

When powered back on, the new ring will offer higher brightness and coherent flux

Small, round electron beam profile

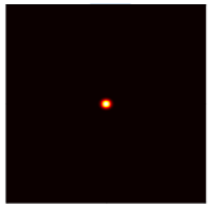


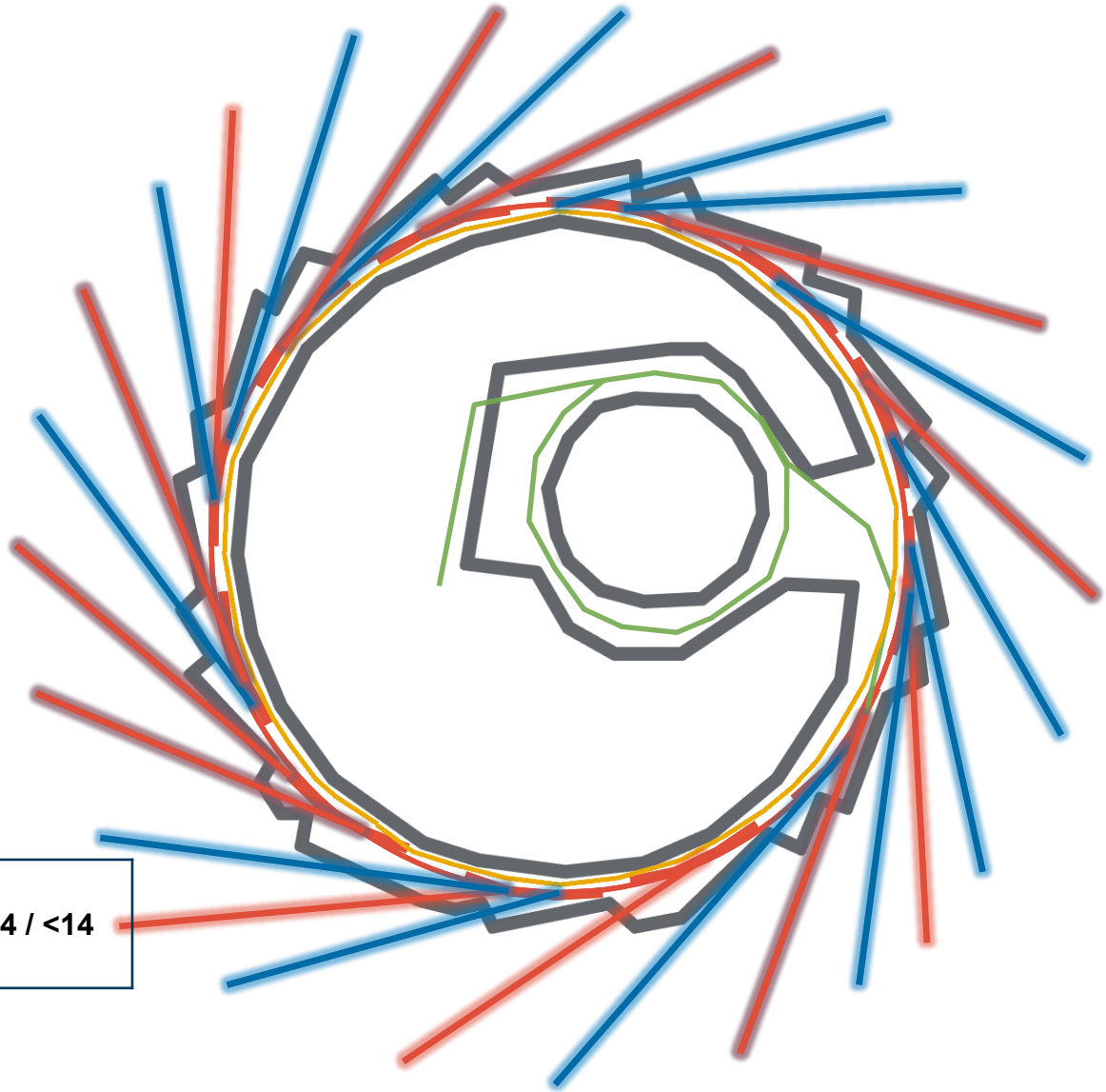


beamsize (σ_x/σ_y) @ ID center	**<14 / <14**

ALS-U will renew the ALS for decades to come, as it continues to innovate

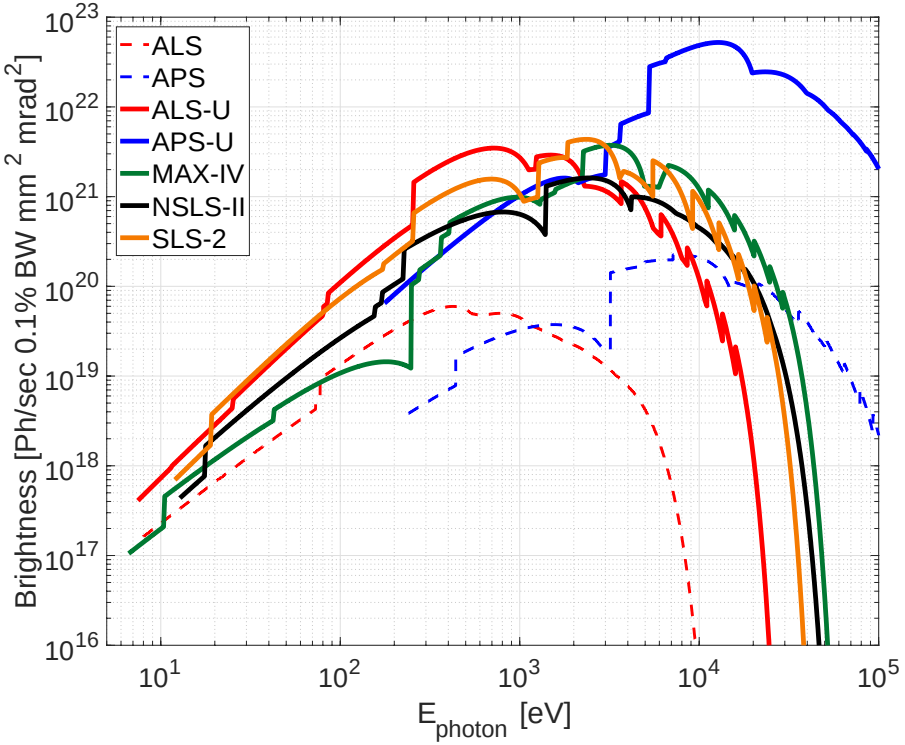
Small, round electron beam profile



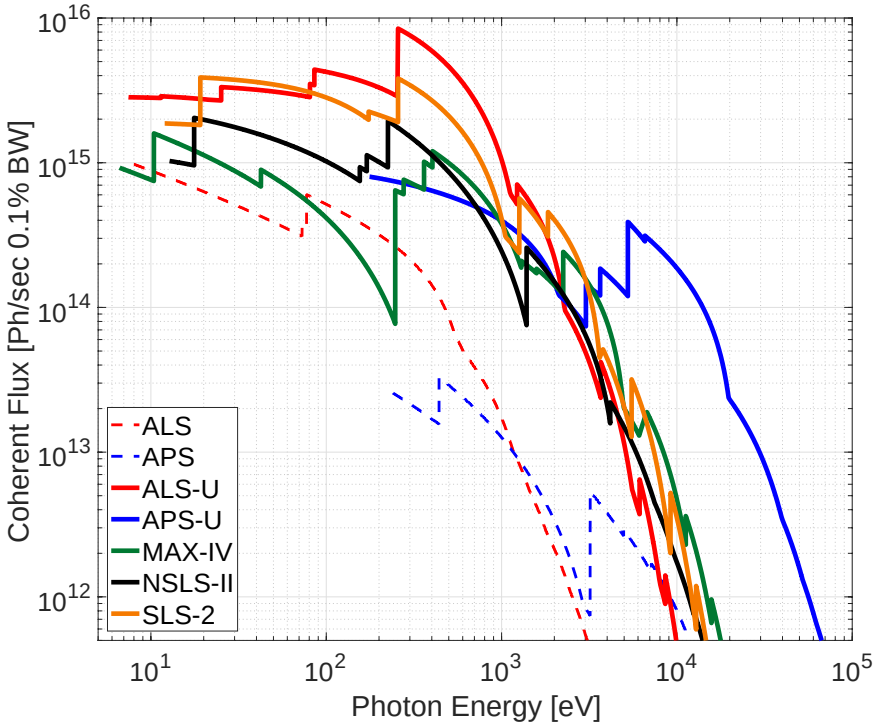


beamsize (σ_x/σ_y) @ ID center	**<14 / <14**

ALS-U performance



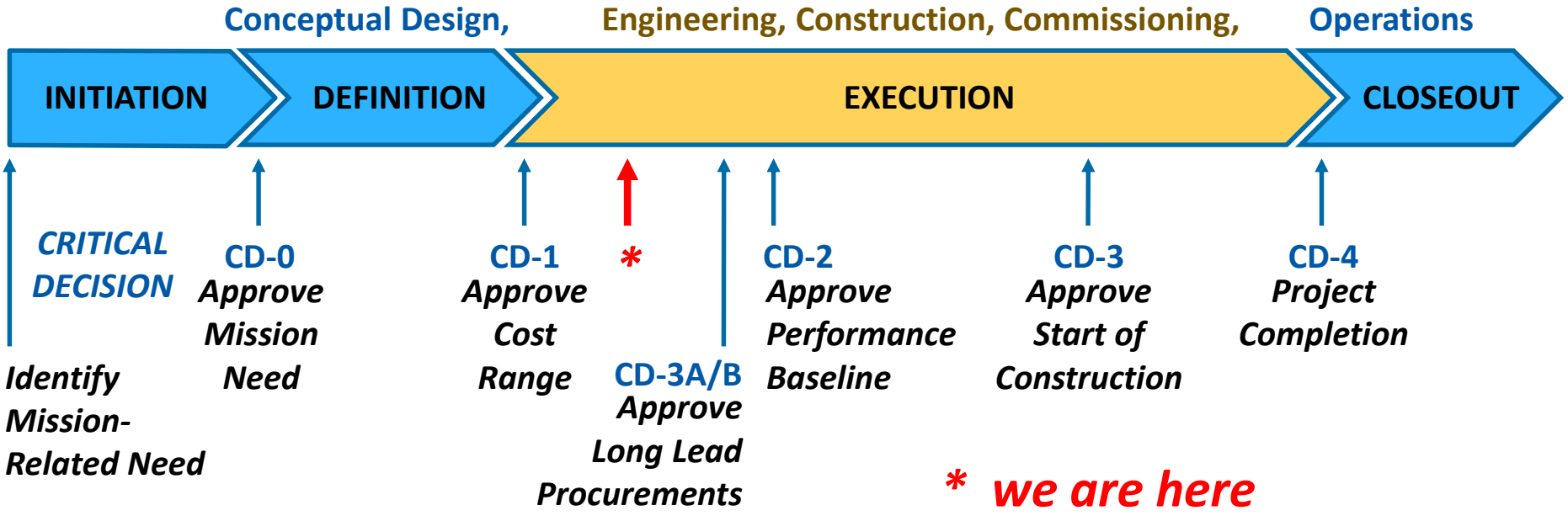
ALS-U brightness compared with other 4th generation facilities (and with ALS / APS)



ALS-U coherent flux compared with other 4th generation facilities (and with ALS / APS)

- 100x increase in brightness and coherent flux
- Higher performance at 100-1,000 eV than any other operational, or proposed, machine
- Beam is almost fully coherent

ALS-U Status

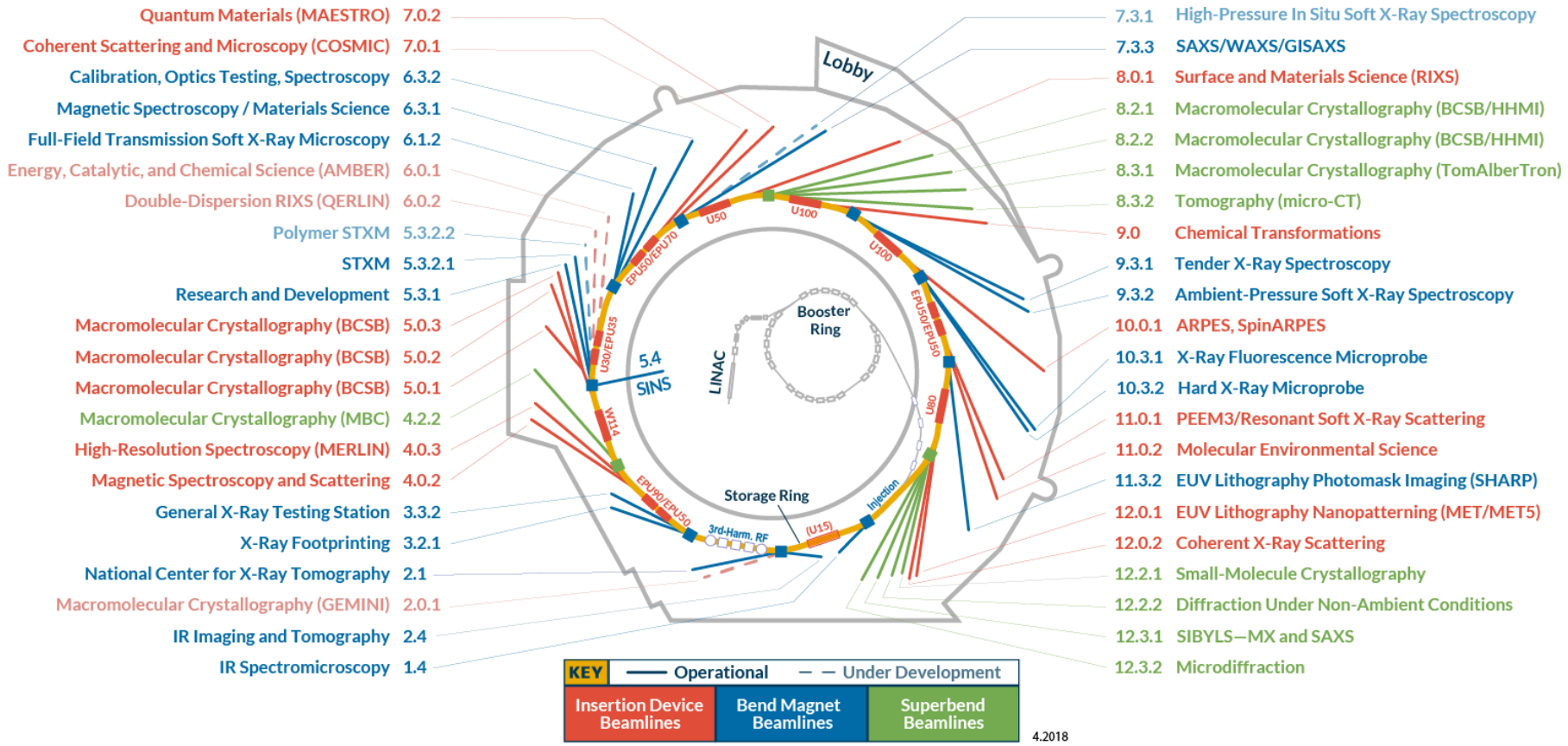


- ALS-U received CD-1 in Sept. 2018
- CD1 included “notional” beamlines
- Extensive outreach program to select new beamlines
- Beamlines are now beginning Preliminary Design
- We are looking to other facilities for engineering solutions and design input

Bending Magnet Beamline Moves

- Goal
- New Source Locations
- Move Types

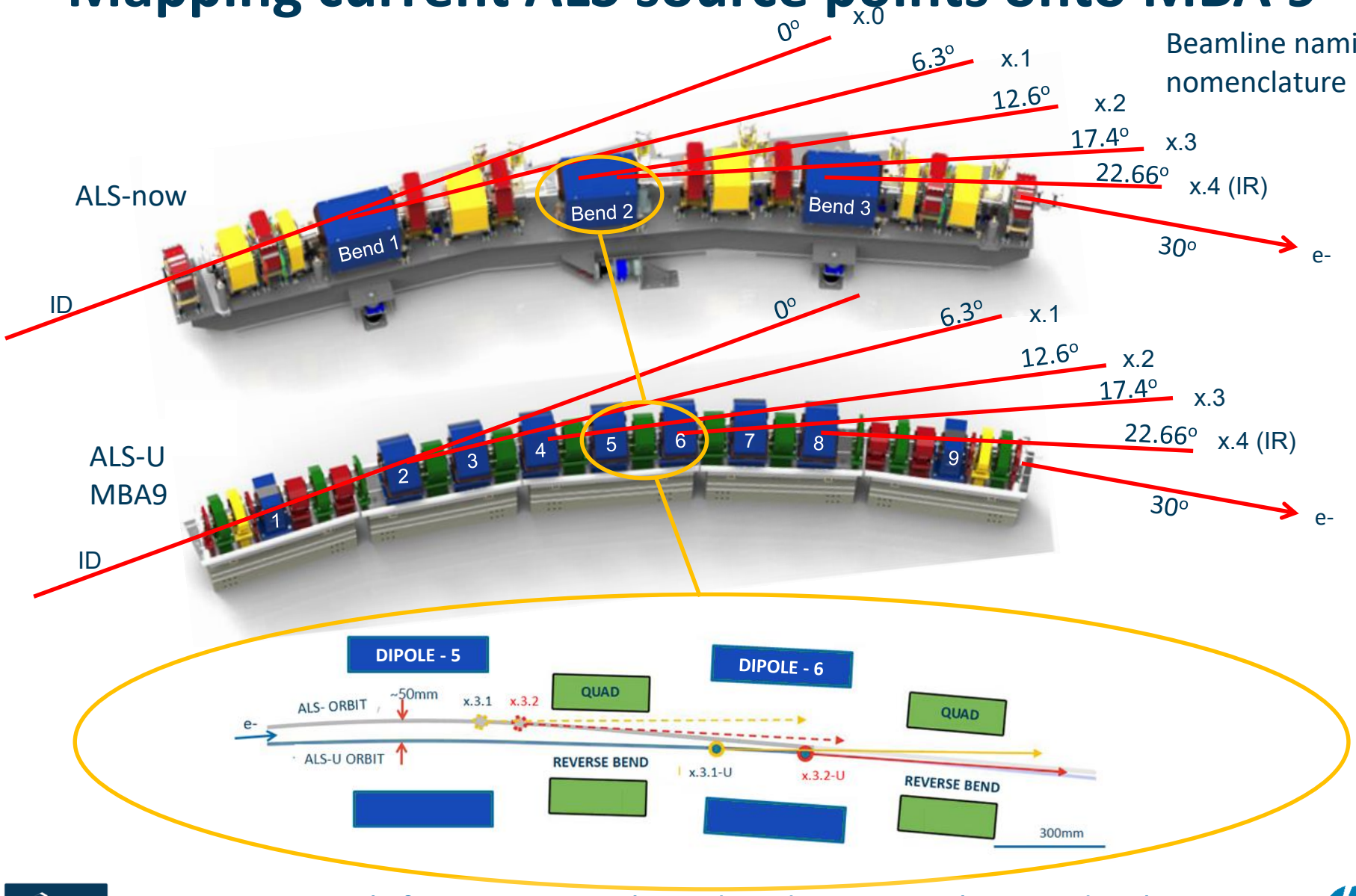
Existing ALS Beamlines



- Insertion device beamlines, mostly for SXRs
- Bend-magnet sources for broadband x-rays
- Superbend magnets for HXRs

~ 60% of beamlines are on bending magnets

Mapping current ALS source points onto MBA 9



Source shift is ~50mm inboard and ~600mm longitudinal

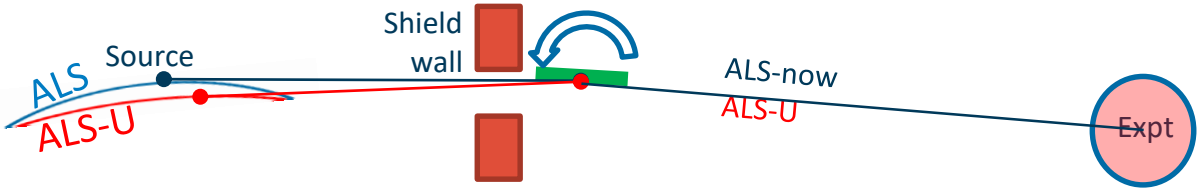
The conceptual design

Number of beamlines

Type 1: Angular move about M1 or end-station

5

Type 2: Angular move between source and M1



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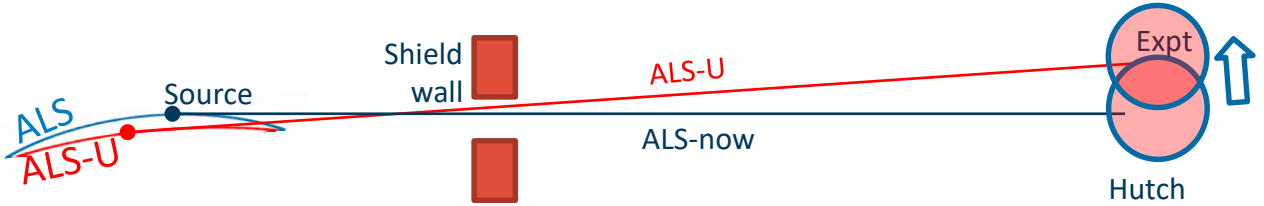
Type 3: Angular and offset move



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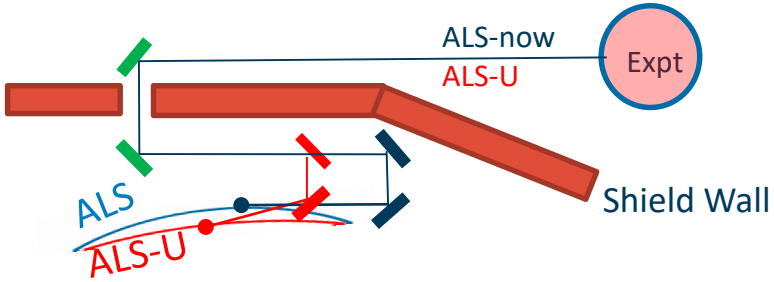
Type 4: Infrared Mount M1 mirror internal to ring vacuum



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For ALS-U Bend Magnet Beamline Moves, each of the 30 existing beamlines are grouped into one of four move types.

Challenges

- Documentation
  - Obsolete / missing documentation
  - Raytraces
- Complexity
  - No two beamlines are quite the same
- Grandfathering
  - Changed construction codes (e.g. seismic)
  - Changed safety rules (safety shutters)
- Timing / logistics
  - Much of the work must happen in parallel during the dark time when accelerator work is also in progress
- Review and approval process
  - ~30 beamlines must be brought back online

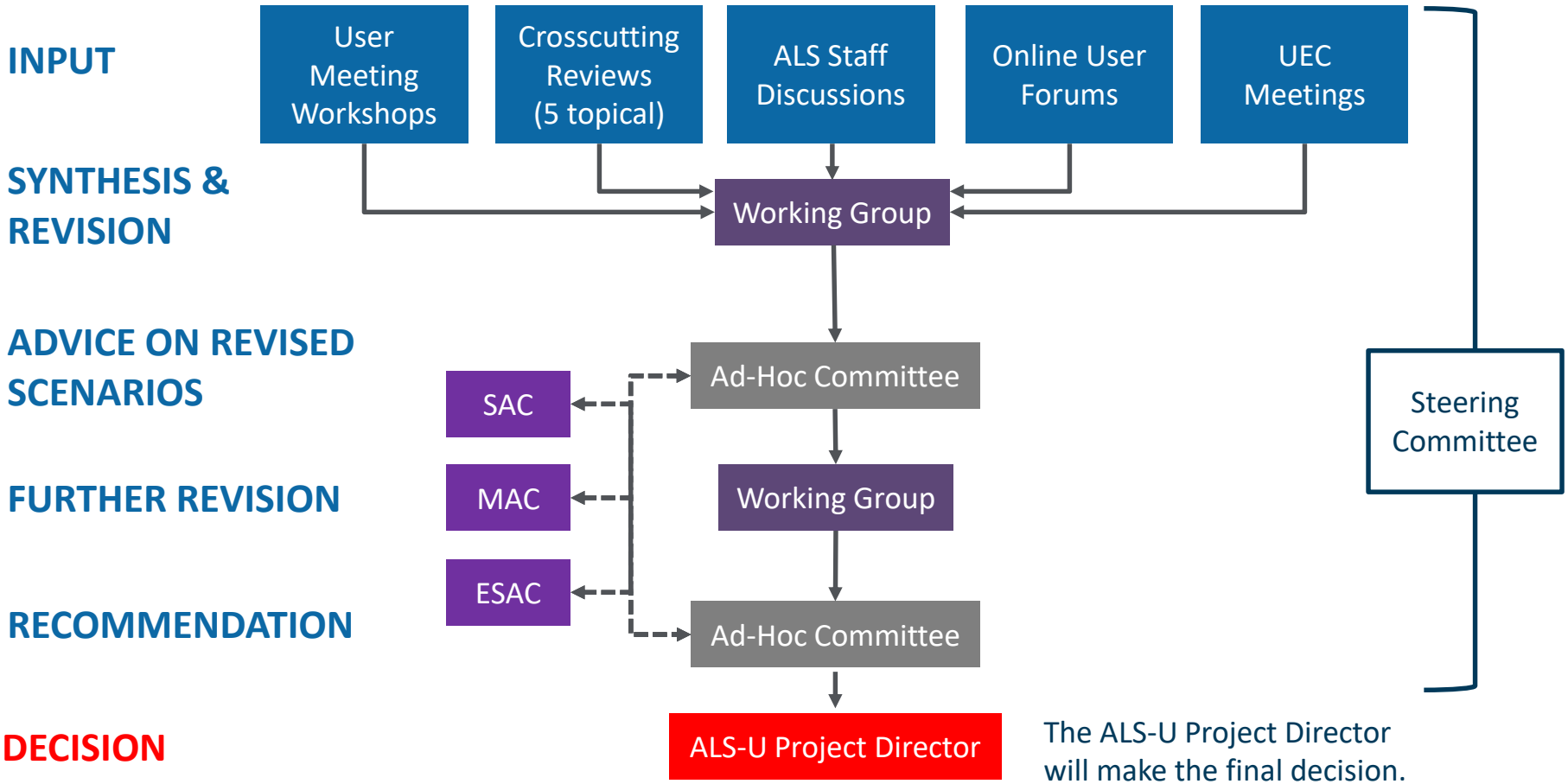
ID Beamlines

- Existing beamlines
- New Beamline Selection
- Flexon
- Tender
- Cosmic
- Maestro

Existing beamlines

- Most ID beamlines will not receive upgrades within ALS-U
  - Beamline upgrade work will continue outside ALS-U
- Those with newer optics will still see some immediate benefit
- Shift to 2.0 GeV
  - Partially offsets lower field strength for bend magnets
  - Changes undulator tuning ranges
  - Increases power loads on frontends and optics
- No impact in most cases
  - Tuning ranges typically exceed beamline energy ranges
  - Gaps can be opened to reduce power load
- Several problem cases identified
  - More analysis required
  - Worst case may require frontend work

Roadmap to Beamline Selection



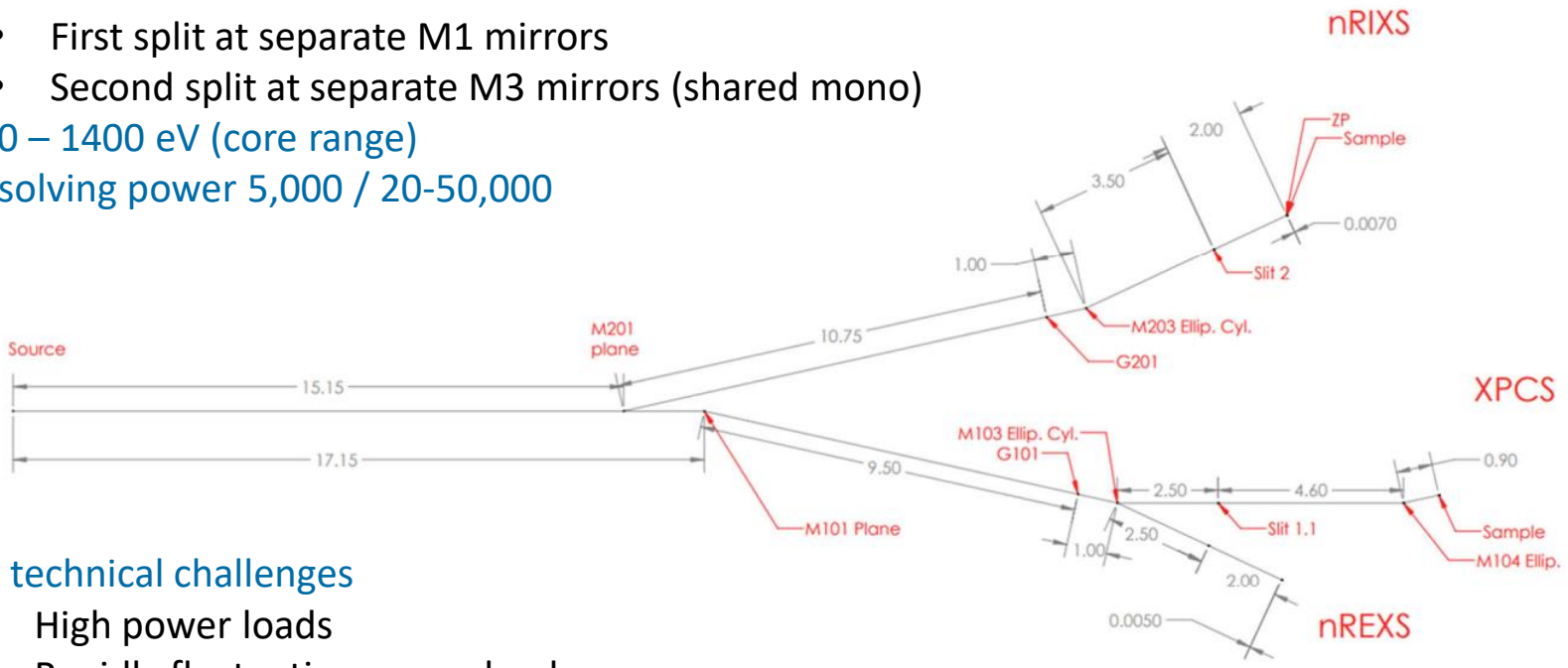
Extensive community input went into the final selection

Final Beamline Selection

Beamline	Techniques	Monochromator, energy resolution, spot size	Insertion device	Core energy range (extended range)	Polarization
FLEXON (new beamline)	XPCS, nRSoXS, nRIXS 3 endstation ports	Branch 1: E/ΔE = 5000, focus: 1 μm (XPCS) and ≤50 nm (nRSoXS) Branch 2: E/ΔE ≥20,000, focus: ≤100 nm (nRIXS)	Full-length Delta or EPU	400–1400 eV (260–1800 eV)	Variable linear, Circular
TENDER (new beamline)	Branch 1: coherent scattering Branch 2: STXM	Branch 1: Grating mono, focus: 10 μm Branch 2: Crystal mono, focus: 100 nm	Full-length Cryo-IVID	Branch 1: 1–5 keV Branch 2: 2-8 keV	Linear
COSMIC (beamline upgrade)	STXM, Ptychography	Unchanged after the upgrade	Existing EPU	250–2500 eV	Variable linear, Circular
MAESTRO (beamline upgrade)	nARPES, micro-ARPES, PEEM	Unchanged after the upgrade	Existing EPU	20–1000 eV	Variable linear, Circular

Flexon – SXR (XPCS, nRIXS, nRSoXS)

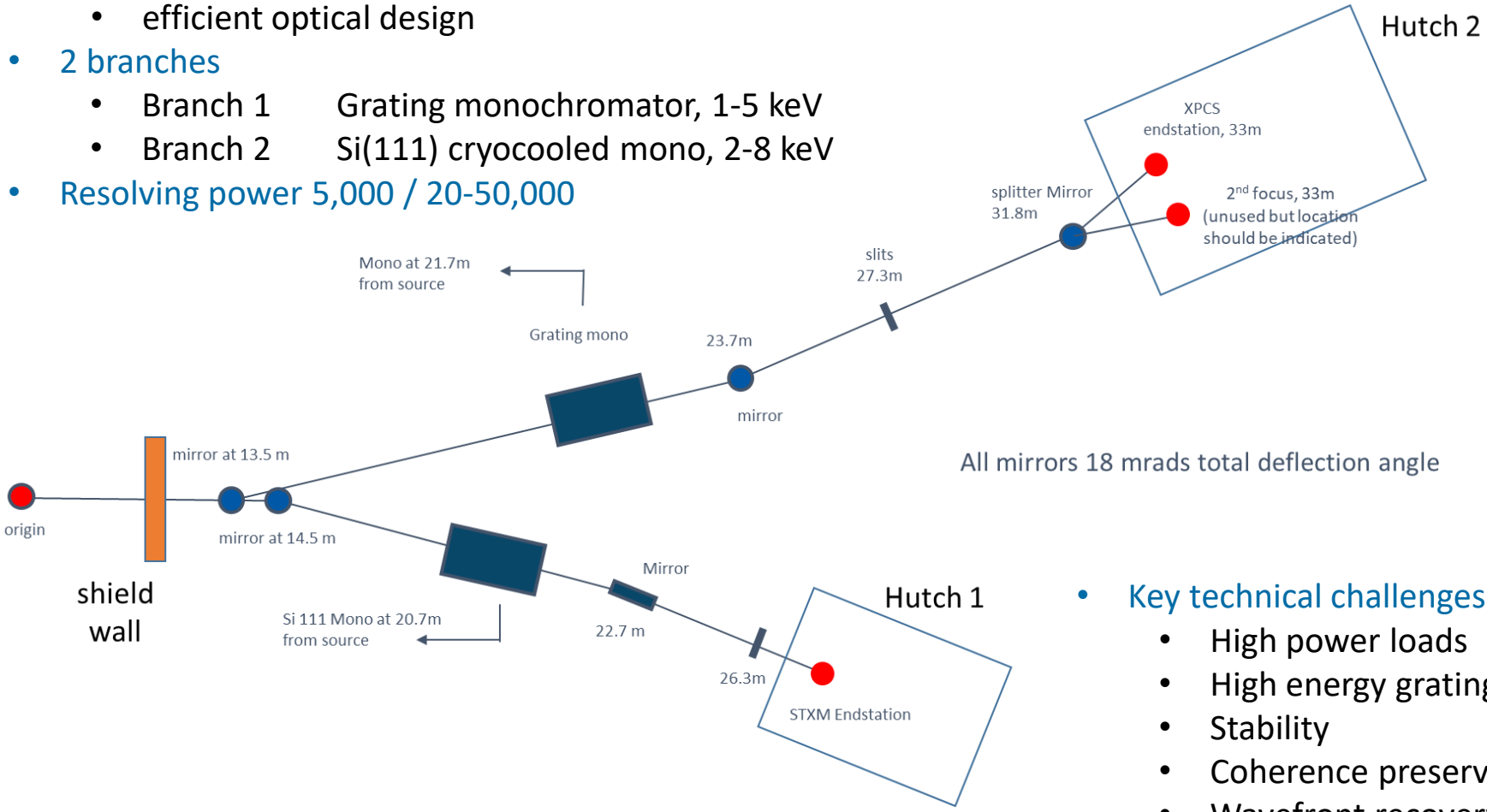
- Optimized for highest possible coherent flux
  - full length delta undulator
  - efficient optical design
- Full polarization control (incl. full 180 degree rotation in linear mode)
- 3 branches
  - First split at separate M1 mirrors
  - Second split at separate M3 mirrors (shared mono)
- 400 – 1400 eV (core range)
- Resolving power 5,000 / 20-50,000



- Key technical challenges
  - High power loads
  - Rapidly fluctuating power loads
  - Stability
  - Coherence preservation
  - Wavefront recovery

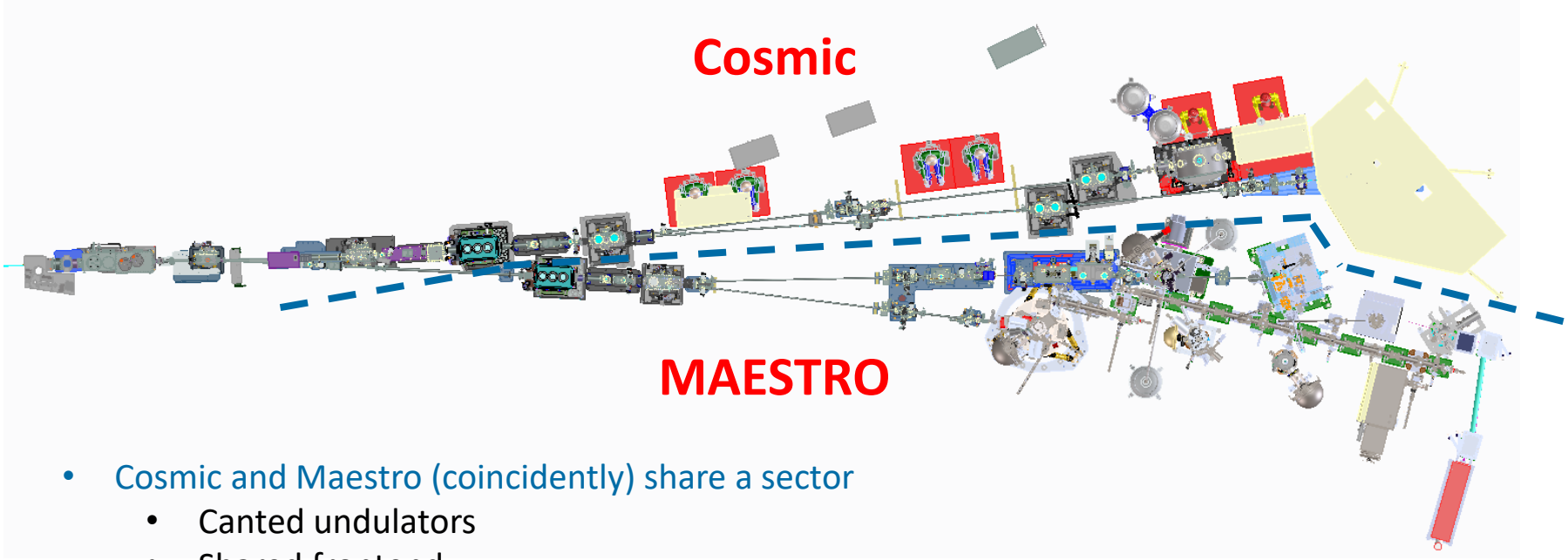
Tender – coherent scattering, STXM

- Optimized for highest possible coherent flux
  - full length cryo-IVID (Ad-hoc committee recommendation)
  - efficient optical design
- 2 branches
  - Branch 1 Grating monochromator, 1-5 keV
  - Branch 2 Si(111) cryocooled mono, 2-8 keV
- Resolving power 5,000 / 20-50,000



- Key technical challenges
  - High power loads
  - High energy gratings
  - Stability
  - Coherence preservation
  - Wavefront recovery

Beamline Upgrades- Cosmic and MAESTRO

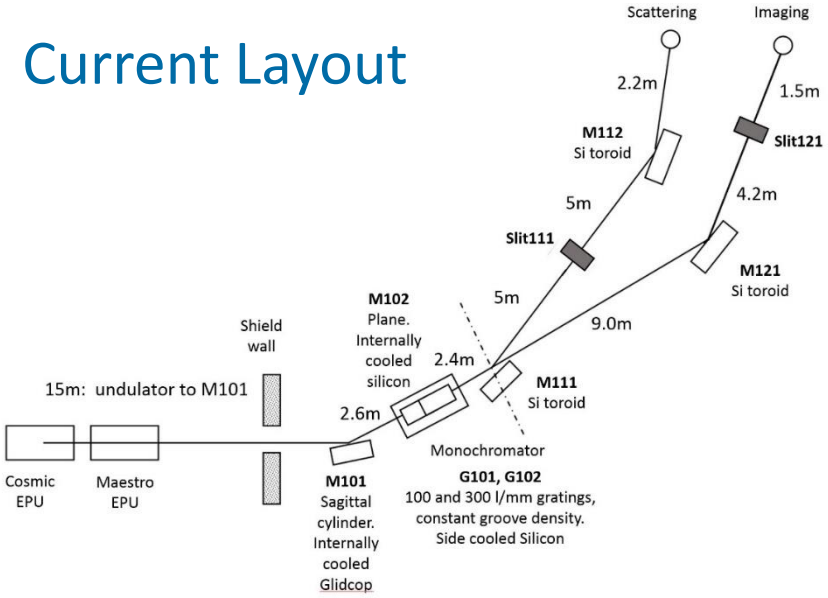


- Cosmic and Maestro (coincidently) share a sector
  - Canted undulators
  - Shared frontend
  - Poses severe space / engineering constraints

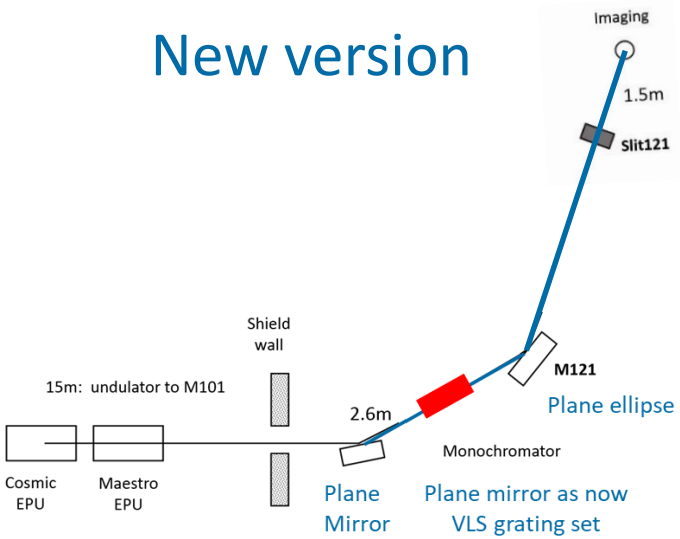
- COSMIC
  - Currently flagship coherent techniques beamline
  - Branch 1: STXM / ptychography
  - Branch 2: XPCS
- MAESTRO
  - Photoelectron spectroscopy, bandmapping, and imaging
  - Branch 1: MicroARPES / PEEM
  - Branch 2: NanoARPES

Cosmic upgrade

Current Layout



New version



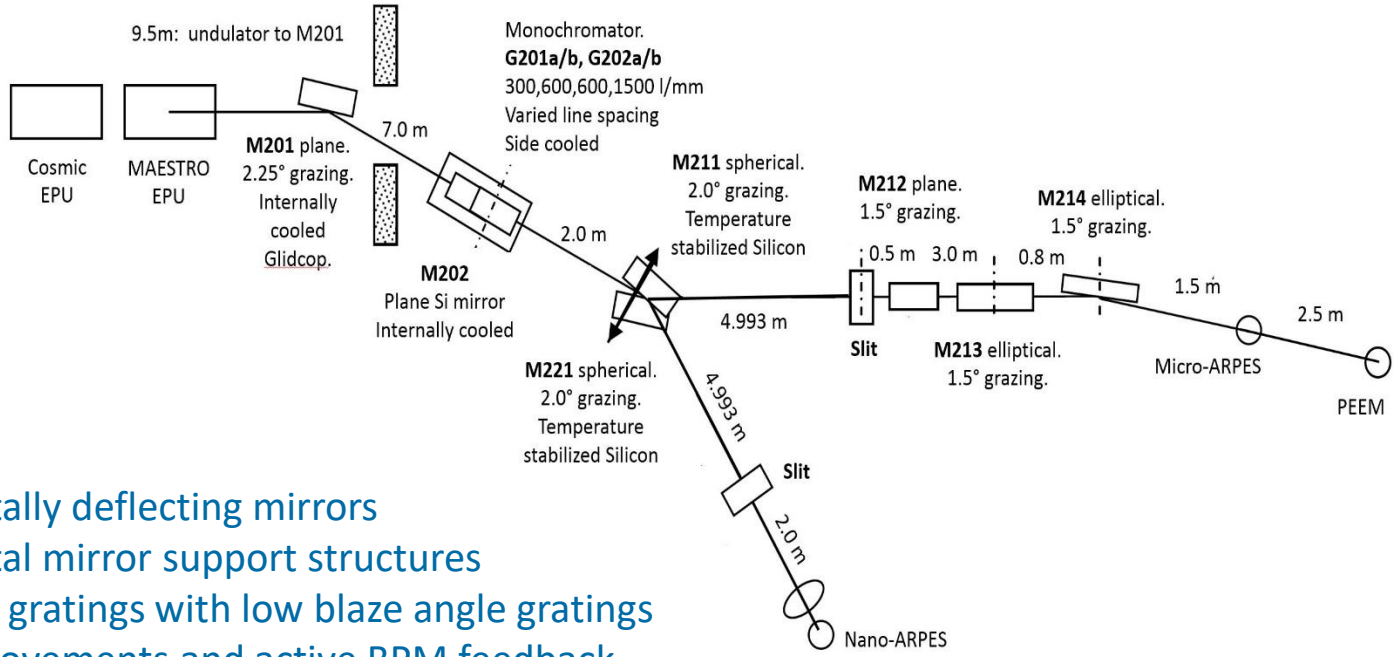
Upgrade Scope

- Scattering branch eliminated (moves to Flexon)
- Imaging beamline downstream of mono will be realigned
  - Approximately follows the line of the current scattering branch
- Replace horizontally deflecting mirrors
- Replace horizontal mirror support structures
- Replace lamellar gratings with low blaze angle gratings
- Diagnostics improvements and active BPM feedback

MAESTRO Upgrade

Current properties

- 60(20) – 600(1000) eV [optimized range (stretch range)]
- Resolving Power 10,000-30,000 (30,000 at 60 eV)
- Beam size in micro-ARPES 10μm
- Beam size in nano-ARPES 120nm (60nm)



Upgrade scope

- Replace horizontally deflecting mirrors
- Replace horizontal mirror support structures
- Replace lamellar gratings with low blaze angle gratings
- Diagnostics improvements and active BPM feedback

Conceptual layout of Upgraded BL B – MAESTRO

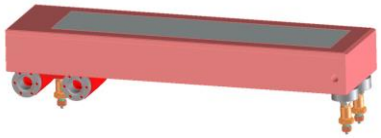
Technical challenges

- Challenges
- R&D examples
- Engineering needs

Technical Challenges

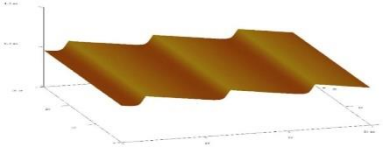
Coherent optics requires ~1 nm rms surface height errors, *from all sources combined.*

High-heat-load optics



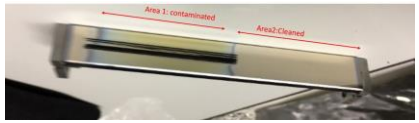
Internal water-cooled Si or LN. Handles dynamic power loading. R&D for **vibration** ≲ 30 nrad, **adaptive** correction

Low-blaze-angle gratings



Process invented at ALS enables higher mono. efficiency. R&D for **full-scale fabrication**.

Contamination mitigation



A few nm of carbon degrades SXR mirrors. R&D to test compatibility of cleaning w/ **coatings** and **NEG pumps**.

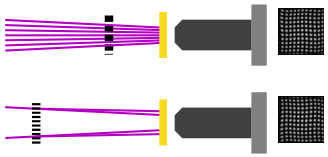
Stability

Reduce vibration from cooling, thermomechanical sources. R&D to demonstrate **in-vacuum stability** at ALS.

Adaptive optics

Correct upstream wavefront errors. Gaining acceptance at facilities worldwide. R&D to demonstrate **vacuum & stability**.

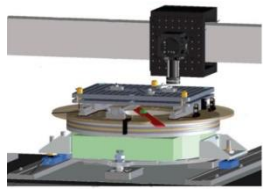
Additional R&D topics



wavefront sensors

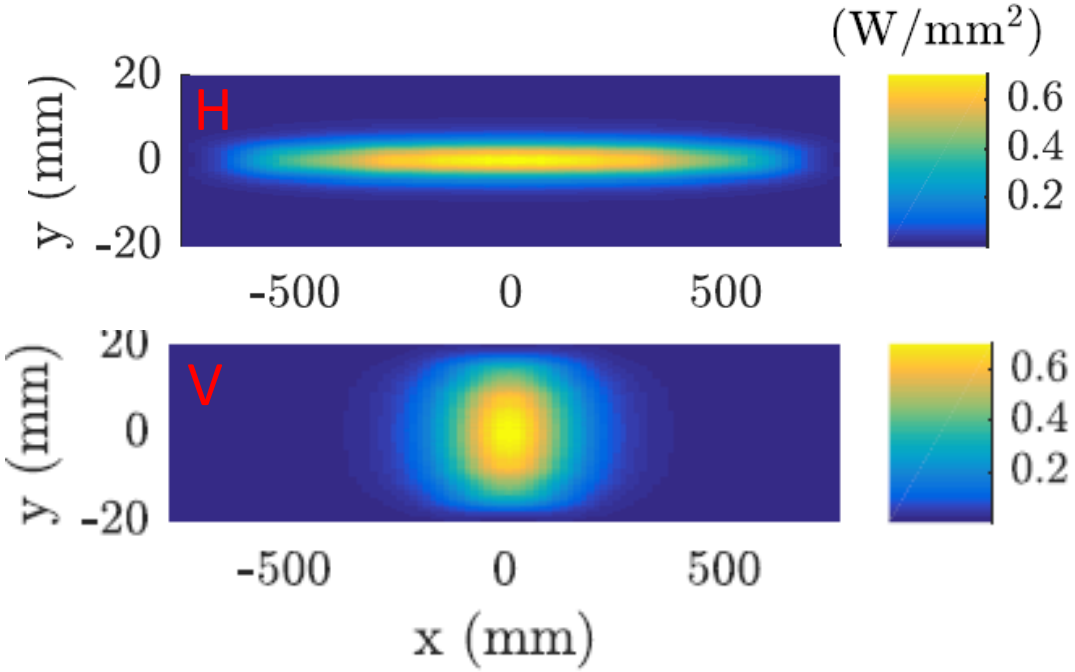
beam position monitors

vacuum systems & practices



ex-situ metrology

High heat load optics

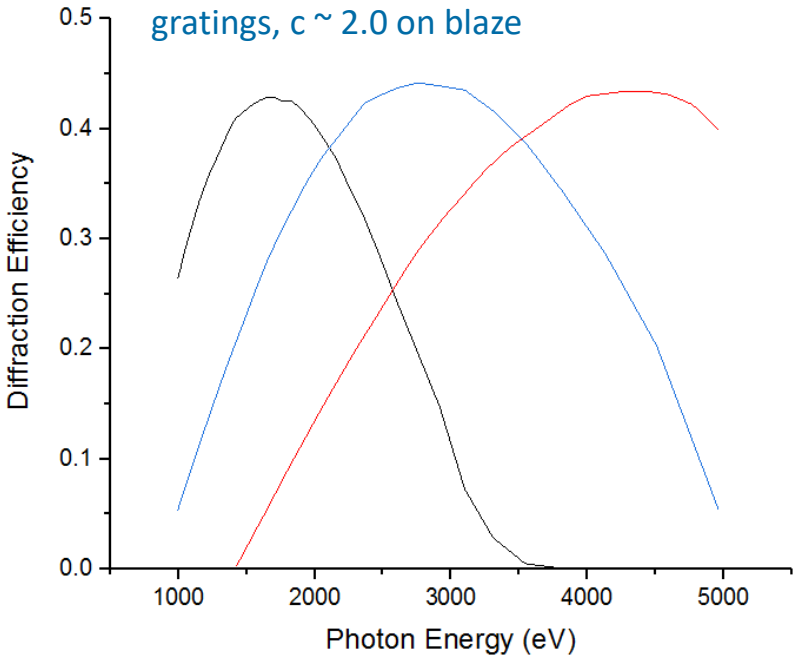


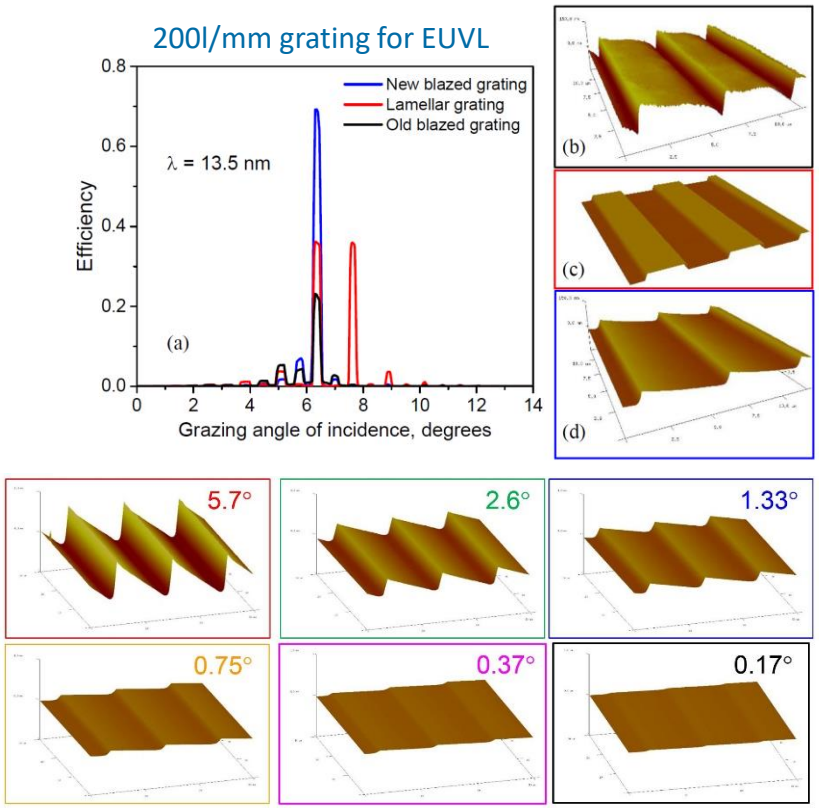
H polarization footprint

V polarization footprint

- M1 subject to large and rapidly varying power loads
- Deformation < λ / 14 required
- Extensive FEA of different cooling strategies (side cooled, internal, LN)
- All solutions require additional adaptive optics correction
- Internally cooled Si is the current baseline
- Increasingly simulation yields increasingly poor results
- Now seriously considering LN cooled M1 mirrors
- Discussions with SIRIUS ongoing
- HHLO review planned for May

Ultra low blaze angle gratings for high energies

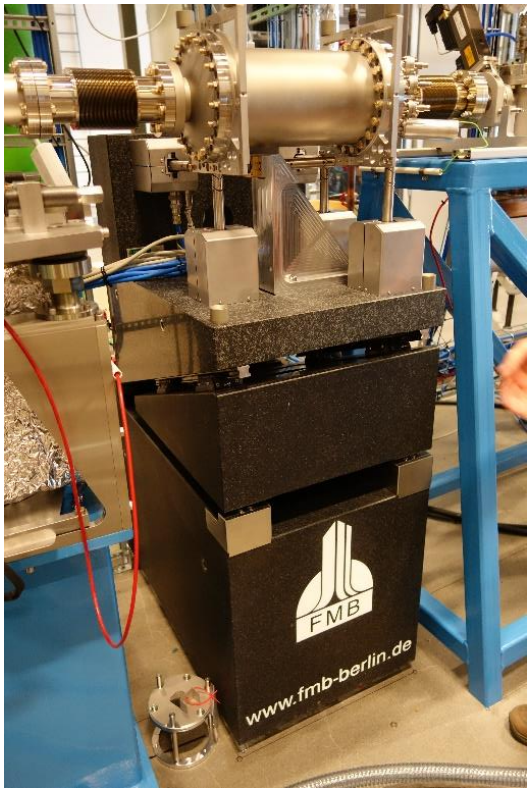




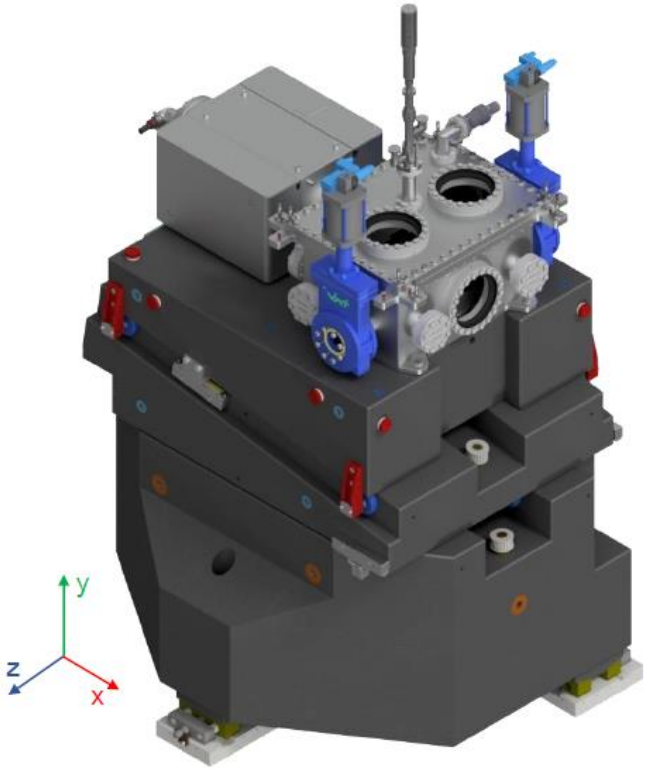
- New process developed at ALS for creating near atomically perfect gratings through anisotropic etching of Si
- can reduce blaze angles through multiple process cycles (smallest so far 0.07°)
- Blazed grating peak efficiency = R/C, so diffraction efficiencies of ~ 40% should be possible
- Allows energy ranges of 1-5keV with high efficiency to be achieved with a single monochromator

Stability and positioning

NSLS-II



MAX-IV

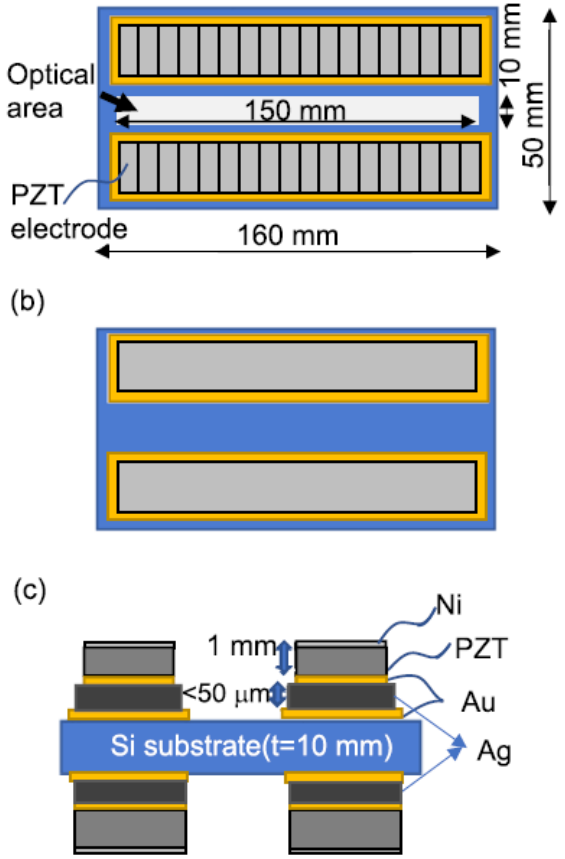


SIRIUS

Actively studying solutions from other facilities

Adaptive X-ray optics

- Adaptive optics will be essential for ALS-U
- Many exciting developments recently
- Diamond / SESO
  - Demonstrated very sophisticated high quality wavefront recovery
- JTEC / APS
  - Glue free bimorphs
  - Super polished
  - Abitrary figures
  - Bakable to 200C
  - UHV compatible
- Observing developments closely



JTEC glueless bimorph

What are we looking for?

- Existing solutions to our technical challenges
- Existing standard designs that can be adopted or adapted
  - Frontends
  - Optics cooling / stability / positioning
  - Diagnostics
  - In-situ cleaning
- Expertise and experience at other facilities
  - Analysis, design, metrology, fabrication, optics cleaning
- Logistical advice
  - Procurement, safety approvals, DoE 413 experience
- Lessons learned
  - Approaches that failed
  - Mistakes that were made

Conclusions

- ALS-U is entering Preliminary Design phase
- Project goals include:-
  - Retain existing beamline capabilities
  - Construct 2 new beamlines
  - Significantly upgrade 2 further beamlines
- Technical challenges are being identified and addressed
- Reference designs are being developed / baselined
  - Input welcomed from other facilities

We're Hiring!

- Multiple immediate openings for:-
  - Mechanical engineers
  - CAD designers
  - Electrical engineers
  - Controls Engineers
  - *etc. etc. etc.*

https://als.lbl.gov/als-u/careers/